Comparing this liability of error in the bisection of each star, in obtaining its distance from η, with the whole liability to error in distance, which is 0·24″, it follows that probably the whole error in the distance measures arises from the bisection, and that therefore the film has remained undisturbed in the direction of distance. Another practically important conclusion is that the exposure of the plates should not continue beyond the time necessary to form distinct disks of the stars to be measured, inasmuch as an increased enlargement of the photographic image necessarily entails an increased error in its bisection (see Table V). Hence, if the stars to be measured differ very greatly in magnitude, then it may be desirable to connect the brightest stars with the fainter by means of stars of intermediate magnitude.

Such, then, appears to be the comparatively rigorous character of photographic measurement: but I hope to carry the investigation still further, by the application thereof to the determination of stellar parallax, for which the method appears to be eminently adapted.

Another investigation presents itself in the inquiry as to the effect of atmospheric absorption at varying altitudes on the image impressed.

With regard to the question of the permanence of the film, it would at present be premature to speak: it might be unsafe to argue from the known permanence of the collodion plates on which the lunar images are impressed, but so far as the present knowledge suggests there is no evidence of deterioration. I propose, however, to measure a few distances periodically, as well as the diameters of the larger star disks.

"Contribution to the Study of Intestinal Rest and Movement."

By J. Theodore Cash, M.D. Communicated by T. Lauder Brunton, M.D., F.R.S., &c. Received May 25. Read May 27, 1886.

During the last two years, as opportunity has permitted, I have been engaged in an experimental study of the various factors which contribute to movement or rest of the small intestine.

This research has furnished me with much information of an analytical character, but it seemed desirable to supplement and, in some degree, to control this, by investigating the general conditions which influence such changes in a healthy animal in which all the functions exerting an influence upon the viscera are in full operation. The most promising means for effecting this purpose appeared to be the establishing of a Vella's fistula which would permit of thorough

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examination without the necessity of subsequent employment of anæsthetics or of operative procedure.

This operation consists in making a double division in the continuity of the small intestine, the approximation by means of sutures of the upper and lower ends of the gut which are to be returned to the abdominal cavity to serve their previous purpose as a part of the intestinal tube, the bringing outwards of the two ends of the intestine which has been isolated from the rest of the tract by the double section, with a view to the subsequent healing of these two mouths in the abdominal incision. The mesentery is interfered with as little as possible in making the intestinal division.

Operation.—Upon a healthy dog weighing 14 lbs. deeply under the influence of morphia, I performed this operation, separating from the rest nearly 20 cm. of the upper portion of the jejunum, which was dealt with as above described.

The dog was kept warm, and the day after the operation received several spoonfuls of milk. The quantity was increased rapidly, and on the fifth day meat was given; by the sixth day the animal was practically normal, the condition of the wound in the abdominal walls, which was now granulating and painless, being all that could be desired. A further rest of three days was, however, allowed in order that all danger of prolapse of the intestine in lifting the animal might be avoided.

No hypnotic or anæsthetic was employed in any of the experiments to be described in this paper, nor was any more restraint exercised than by occasionally laying a hand on the head or body of the dog in token that he was to remain still. As regards the disposition of the animal, his attachment to myself and the laboratory attendant was such, and the inconvenience of the experiment so little, that when brought into the laboratory he often endeavoured to leap on to the table on which he rested whilst under examination. When placed on his side on this table he remained, as a rule, perfectly quiet, except for an occasional deep respiration, a start during sleep, or a stretching of the limbs.

On examining the floor of the short wound in the middle line of the abdominal parieties, the two round mouths of the fistulous intestine with their everted mucous membrane could be readily observed, and their movements noted without the least difficulty. There was a space of 2 cm. intervening between these two mouths which was filled by the parietal peritoneum muscles and skin which had been divided in the operation, and subsequently united by suture to the corresponding structures of the opposite side. At the time the experiments commenced firm union had occurred in this position.

Observation of the Fistulous Opening during Hunger, Feeding, Exercise, &c.

If the animal was in a condition of hunger (it received one large meal of meat about the middle of each day, and manifested a desire for food therefore when brought up to the laboratory about 10 o'clock in the morning) the appearance of the mouths of the fistula varied from time to time.

After a certain amount of movement had taken place, it often happened that a period of complete repose of 3 or even of 8 to 12 minute occurred without any contraction making itself manifest; then, spontaneously, movements of one or both mouths of the fistulous gut made their appearance, which sometimes appeared to be either sequences to acts of swallowing on the part of the animal, or results of mental impressions.

These contractions usually evidenced a very regular rhythm, but varied greatly in strength.

Those first occurring were frequently so slight that they could only be observed by the change of position in the light reflected by the moist mouth of the fistula. Increasing in strength they reached a maximum, and, after persisting for a time (30″ to 3′ or 4′), gradually declined or suddenly ceased. When peristalsis followed an act of deglutition, the effect was of shorter duration and culminated more rapidly, duration of the contractions was usually shorter, and the advent of their maximal strength more rapid.

If when only gentle and occasional movement of the mouths of the fistula, attended by little or no extension of secretion, was occurring, the animal was allowed to jump down on the floor and encouraged to run a few times round the room, it was found on continuing the observation after the exercise, that the contractions were much more frequent and powerful, and were sometimes associated with the ejection of increased secretion from the lower fistulous opening.

During the condition of hunger, *i.e.*, before the animal had received its daily meal, the smell of food, but much more markedly the swallowing of several pieces of meat successively presented to the animal, had for effect a regular and powerful series of contractions, usually attended with an increased ejection of secretion.

It was evident therefore that without the least interference with the fistulous intestine, the appearances coincided with the experiments I recorded graphically, and which I shall now consider in more detail.

Graphic Experimental Records.

For the purpose of recording merely an intestinal contraction near the orifices of the fistula, a fine glass cannula slightly enlarged at the end, upon which was fixed a small bag of delicate elastic membrane,

was employed. This constituted the "sound," and was connected by means of a system of thick-walled india-rubber tubes with a mercurial manometer or a Marey's recipient tambour; if the former was employed water was the means of communicating the impulse from the compressed sound; if the latter, air. The sound, whether inflated with air or distended with water, had a diameter when fully filled of 7 mm. at its widest point and a length of 12 mm. The manometer was so arranged that the level of the mercury was as nearly as possible that of the sound resting in the intestine. Occasionally two sounds, each connected with a separate manometer, were used, one being introduced through the upper, the other through the lower mouth of the fistulous intestine. When it was desired to register the speed of propulsion of a solid body through a portion or the whole of the length of the fistulous intestine, a modified form of the method used by Mosso, and developed in its details by Ranvier in experiments upon the œsophagus, was employed. In this case the travelling sounds were oblong bodies having rounded ends, and measuring in breadth from 5 to 9 mm., in length 12 to 14 mm., and were made of metal, cork hollowed out, or glass, and in several experiments a solid sound was replaced by a small piece of lean meat. Those made of metal were the thin-walled silver capsules which Prof. Kronecker employs for the introduction of his maximal thermometers into the alimentary canal of animals. They are perforated with one or two holes which serve for the attachment of a thread of silk. The larger of the metal capsules which I employed as a travelling sound was 9 mm. broad by 14 long, and weighed 3·4 grams; the smaller, 6 mm. by 14, weighed 2·2 grams.

The registering apparatus consisted merely of a thin wedge of cork bearing a glass pen, and travelling vertically by means of two glass eyes passed through its substance upon parallel steel guides. The weight of this falling pen was 2 grams. A fine silk thread from the sound to the pen passed over two pulleys, one placed opposite and in the same plane as the fistulous opening, the second vertically above the steel guides of the travelling pen. When traction was made by the sound the pen was drawn upwards, its elevation being directly proportional to the extent of withdrawal of the sound from the lower pulley.

For each observation the dog was placed on its side with the fistulous opening opposite to and at the same level as the lower pulley; the sound was introduced into the upper fistulous opening, the upper pulley raised so that the pen was drawn upwards for a few centimetres from its support,* and the drum arranged so as to leave the whole

* The respiratory movements were to some extent communicated to the pen connected with the sound. By means of two Marey's tambours the number of respirations was usually written at the same time as the curve of intestinal movement.

breadth of its recording surface available for registration, when the pen should be raised by passage of the sound more deeply into the fistula. A slow rotation of the drum, usually one revolution in about 17′, was employed.

There is no purpose in separating the results according to variation in the experimental method, especially as the fixed sound and the travelling sound were employed with one or two unimportant exceptions in each class of experiment.

It may be stated generally that although during a condition of fasting occasional contractions make themselves manifest, the record obtained from a fixed sound sunk 4 cm. into the fistulous intestine shows that periods of complete quiescence are the rule, and movement (as evidenced by contraction around the sound) the exception. When a period or phase of peristaltic activity begins, the first contraction manifests itself, usually by a faint impulse communicated from the sound of the registering apparatus. This is generally succeeded by a series of waves of uniform frequency, but varying in their extent. The repetition of the contractions may, however, show a slight variation; thus, during the first part of a phase the wave contractions may be at first eight in a minute, then nine, and again eight before cessation.

The following notes fairly indicate the phase of quiescence and of contraction occurring in the intestine.

Experiment Records.

Experiment I.—The sound, slightly distended with water (diameter 5 mm.), was introduced into the upper fistulous opening; the animal had not fed for fourteen hours, and was evidently hungry.

0′. Introduce sound.
5′. Up to this time rest.
5′ to 6′ 40″. Feeble contractions, succeeded by 6′ rest.
13′ to 16′. Gentle contraction succeeding slight movement of animal during which it swallowed.
26′. About a teaspoonful of water was introduced into mouth; as a result three distinct swallowing movements occurred; intestinal contractions developed themselves which continued strongly for 2′; faint contraction for the succeeding 3′.
31·5′ to 39·5′. Rest, except for very faint contractions which may have been communicated by a loop of adjacent intestine. Swallowed, but no definite contraction resulted.
39·5′ to 42·5′. Very faint contractions.
42·5′ to 50·5′. Pause.
50′ 5′ to 53·5′. "Empty" swallow succeeded by feeble contractions for 3′.

53·5′ to 91′. There have been three series of contractions, lasting in all 12′. Two of these were preceded by swallowing, which in the first case was spontaneous, and in the second resulted from rubbing the larynx.

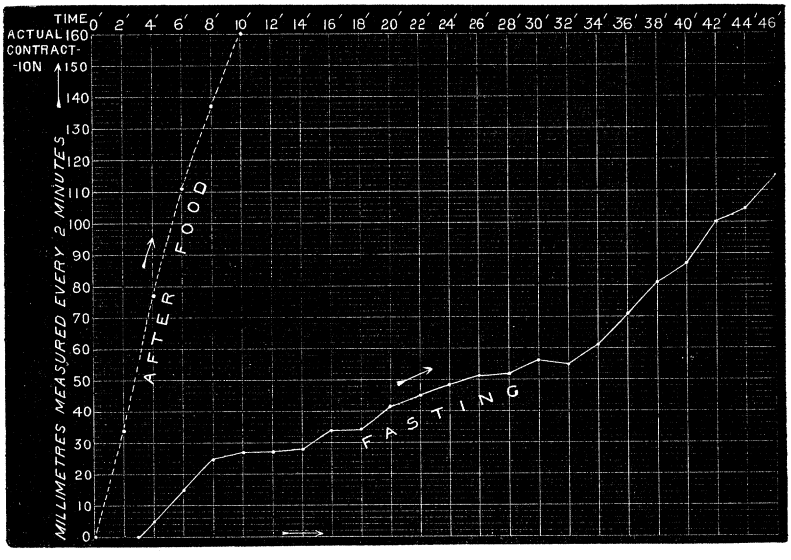
Total in 91′.—In this experiment made upon the fasting animal, out of a total of 91′ active intestinal contraction was present during 9′, faint contractions for 19′ more, and the intestine was at rest for the remainder of the time, *i.e.*, 63′. One-half of the series of contractions were preceded by spontaneous or induced acts of deglutition.

It cannot be demonstrated by the fixed sound method that the contractions are any more than local contractions, but as the occurrence of these for any length of time greater than 1′ or 2′ is very exceptional, and is almost always a prelude to propagated contraction, we may assume with certainty that many of the long-continued phases of contraction were propagative, or in other words they would have propelled the sound downwards if it had been movable.

From simple observation of the fistulous opening made immediately afterwards, no sound having been introduced, I found that the number of the series of contractions were in the two cases equal, but that in the sound experiment their duration was slightly longer.

An experiment made during a condition of hunger, but with a travelling sound, will now be recorded.

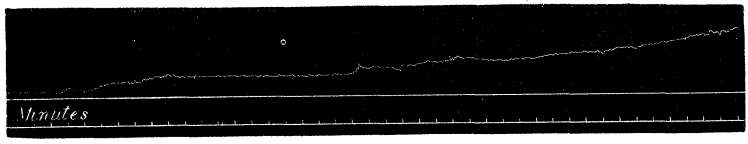
Experiment II, Chart I. Experiment VII, Chart VI.



Experiment II (Chart I (continuous line, diagrammatic), and Curve I).—The dog had not been fed for nineteen hours. A small sound consisting of $\frac{1}{2}$ gram of lean meat on which a little piece of tendon was left, was attached by a thread to the pen already described which moved vertically upon guides.

This sound was introduced deeply into the upper fistulous opening. The following notes indicate its progress through the fistula:—

Experiment II, Curve I.



Reduced scale = $\frac{1}{7}$th.

0′. Sound introduced into the intestine.
4′. Definite peristalsis has commenced; animal sleeping.
7′. Roused; a little movement with deep respiration.
17′. Again asleep; gentle peristalsis.
19′. Started in sleep and awoke. The loop of intestine was evidently twisted or moved away from former position (roll movement) to which it shortly returned; again sleeping.
21′ 5″. Roused. Deep respiration with slight peristalsis.
33′. Propulsive peristalsis, strong and regular.
Dog roused just before expulsion of sound from the lower opening. (The meat was not in the least degree digested.)

It will be observed that during sleep the sound continues to travel forwards with considerable regularity. In all 12 cm. of the fistulous intestine is traversed in forty minutes.

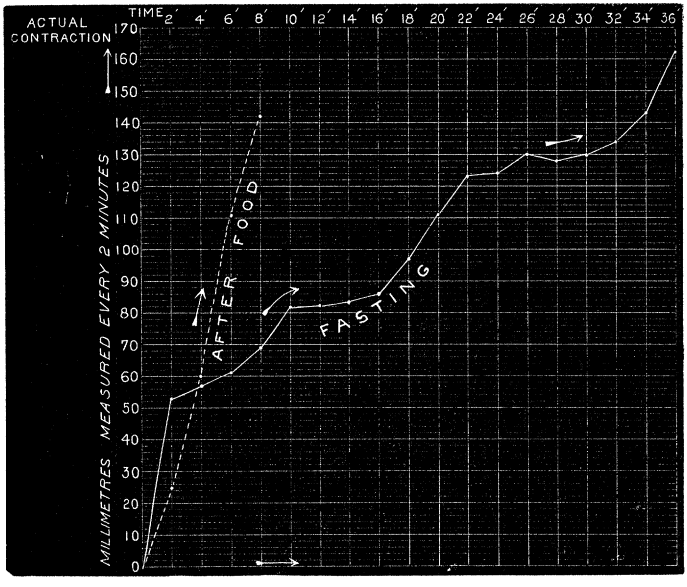
The experiments of Ranvier have shown that if a travelling sound which is passing down the œsophagus be hindered in its transit by traction being exerted upon a thread connected with it, the contractions become inoperative, *i.e.*, fail to forward the body, and then cease, the muscular tube becoming "accustomed" to its presence. The same holds good if we introduce a moderately large sound into the intestinal fistula and allow it to travel. The fact of its introduction and presence favours its passage onwards for a certain distance with considerable rapidity; but if gentle traction be made on the thread after a period of active but futile contraction,* rest occurs and no advancement takes place till a new phase of activity develops itself.

*. These contractions are local. I have hardly ever seen them pass the body whose presence is to a large degree the cause of their occurrence and travel to a lower part of the intestinal tube.

It is thus that during a fasting condition, the sound being unrestrained, the first part of the fistulous intestine is traversed rapidly; but that afterwards a marked diminution in speed occurs, whilst with a smaller sound moving freely, or a larger sound restrained for a time, the rapid initial peristalsis would not be observed.

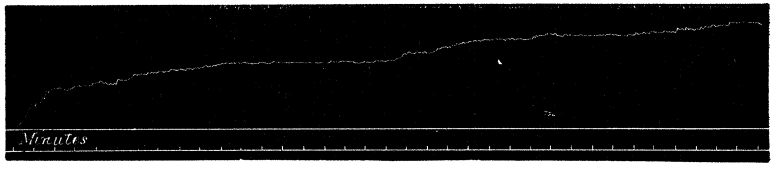
In illustration of this point I give the notes of an experiment.

Experiment III, Chart II. Experiment VI, Chart V.



Experiment III (Chart II and Curve II).—0′. Introduced large oblong sound (metal capsule, weight 3·4 grams, 18 mm. long by 9 mm. greatest breadth) into upper fistulous opening. Sound allowed to travel, no traction being made upon it but that occasioned by the weight of the pen (2 grams).

Experiment III, Curve II.



Reduced scale = $\frac{7}{15}$ths.

1′. Active propelling peristalsis; sound has travelled 2 cm. into intestine.
2′. Continuation of active peristalsis; sound advanced in all 5·2 cm. (At this time effect due to the introduction of sound passes off, and advancement occurs more slowly; local non-propulsive movements taking place from time to time.)
8′. Has advanced in all 7·4 cm.
14′. Has advanced in all 8·2 cm.
18′. Advancement has been slow; is now 10 cm. from upper opening of gut. At this point contraction becomes more active.
25′. 12·8 cm. traversed; peristalsis succeeded by a pause.
29′. 12·9 cm.; pause in contractions.
35′. 16·2 cm.; active propulsive peristalsis reappeared. Capsule expelled from lower fistulous opening.

The total time occupied in the passage of the sound through 16·2 cm. of fistulous intestine was 35′.

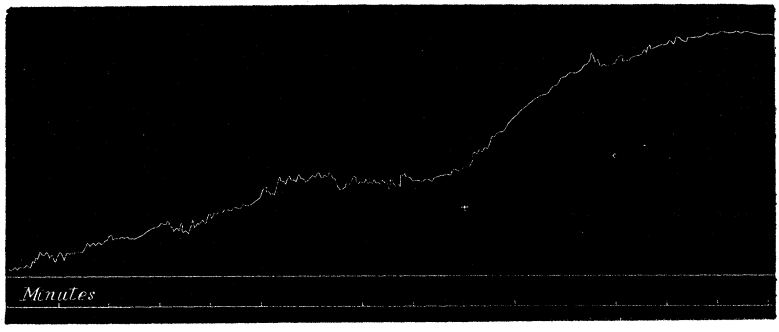
Effect of Feeding.—I will now turn to the effect produced upon the fasting intestine by the introduction of food into the stomach. The method of experimentation will be at once apparent.

A fixed or travelling sound was introduced through the fistula, and the condition of the fasting intestine, as regards its movement, was recorded. At a noted time the dog, whose head had been kept covered with a cloth, had a series of pieces of meat given to it which it rapidly swallowed without changing its position on the table. (The covering of the head was a necessary precaution which I adopted in almost all the observations in order that this experimental procedure should not be associated in the mind of the animal with the administration of food only; for if the dog saw meat when in a condition of hunger, or had its proximity suggested in any way, it was sufficient to produce an active though frequently transitory contraction in the fistulous gut.)

The notes of the following experiment which was made when the animal was showing unmistakeable indications of hunger, will illustrate the modification in an already existing peristalsis on the introduction of food into the stomach.

Experiment IV (Curve III).—
0′. Introduction of large sound, used in the previous experiment.
1′. Active peristalsis has commenced.
3′. Propulsive movements alternate with local or non-propulsive.
5′. The animal was somewhat excited by the movement of a plate on to the table on which it was lying.
7·5′. About 50 grams of meat were presented to the dog in pieces and rapidly swallowed.
10′. Intestine quiet, except for faint local movements around the sound.

Experiment IV, Curve III.



Reduced scale = $\frac{1}{5}$th.

11′. Active peristalsis has developed, the sound passing with great rapidity onwards; so little relaxation occurs that the curve has the appearance of steps at some parts.

16′. Sound lying within lower fistulous opening through passage of which it is retarded by thick muscular and cutaneous walls, which somewhat overhang in this position.

In order to render the alteration in the speed of peristaltic propulsion more apparent, I formulate from the experiment the distance traversed by the sound in every two successive minutes.

Time after introduction of sound in minutes.	Distance accomplished by sound in centimetres.	
	Fasting.	Fed.
0	0	—
2	1·6	—
4	1·0	—
6	2·2	—
8	0·5	—
10	..	0·5
12	..	4·3
14	..	3·1
16	..	2·2

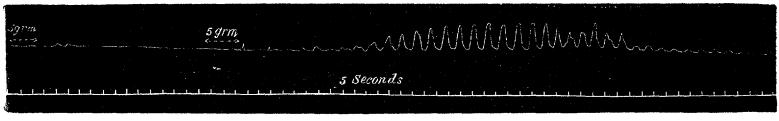
Total for 8 minutes before food..... 5·3 cm.
„ after „ ..... 9·7 „

If we employ a rapidly revolving drum, the time elapsing between the introduction of food into the stomach and the occurrence of con-

traction is easily estimated. It is then found that the intestine from a condition of entire rest or very faint contraction frequently passes with great rapidity to a state of powerful and regular propulsive contraction.

If the movement be registered by a stationary sound connected with a manometer, the course of the contractions occurring at the part of the fistulous intestine surrounding the bladder is recorded. It will be observed then that the individual contractions develop gradually to a maximum, and thereafter decline rapidly, their rhythm or rate of recurrence being very constant throughout.

Experiment V, Curve IV.—Administration of Meat to Fasting Animal during Absence of Contraction of Intestine (fixed sound and mercurial manometer).



Experiment V (Curve IV).—Dog fasting, sound, moderately distended with water, introduced 3 cm. into upper fistulous opening. The contraction round the sound as a result of its introduction and extension occurred regularly at the rate of ten for 1′. After spontaneous movement had ceased the smell of the meat produced excitement with distinct contractions, which did not entirely disappear for 3′ 30″.

0′ 0″. When rest had again intervened, a small piece of meat weighing 5 grams was given.

1′ 30″. Another piece of the same size. Both of these were swallowed the instant they were presented.

1′ 45″. Contraction commenced at the rate of seven in 40″.

3′ 20″. Active contractions reached their maximum. Some tonic contraction is still seen between active compression of the sound, so that the curve remains elevated above the abscissa.

4′ 16″. The active contractions which had been declining markedly for 30″ came to an end, and were succeeded by a series of short waves which lasted for 1′ till at

5′ 16″. The intestine came to rest.

Five minutes later a piece of meat was again offered, faint movement being present at the time, the maximum of the powerful contractions was reached in 40″, in exact correspondence with the former experiment. In the first result there were nineteen well-

marked contractions, having approximately a maximal value; in the second there were seventeen.

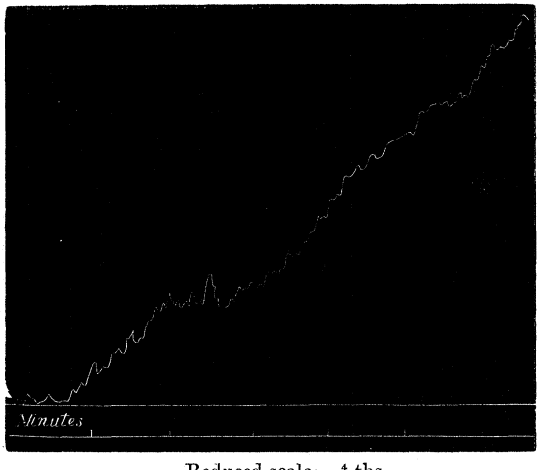
After the lapse of another five minutes, the administration of another piece of meat failed to arouse any contractions.

Immediately after a full meal a travelling sound introduced into the upper fistulous opening is forwarded by a powerful and regular peristalsis to the lower opening and promptly expelled, no marked halt occurring during the passage. Not only do the local contractions manifest themselves to a striking extent, but writhing, &c., rolling movements ("Roll-Bewegungen") of the fistulous intestine are also observed. It is during this period that the most rapid propulsion of the sound occurs, relaxation between the contractions is very imperfect, the sound being held without marked retrogression till the next powerful wave drives it onwards.

The presence of abundant peristalsis in the small intestines generally is evidenced by borborygmi and movement communicated to the abdominal parietes. The increase of secretion which is extruded from the lower fistulous opening, and to a much smaller extent from the upper opening, is very apparent.

I select two experiments for illustration.

Experiment VI, Curve V.—Fifteen minutes after full Meal.



Reduced scale = $\frac{4}{11}$ths.

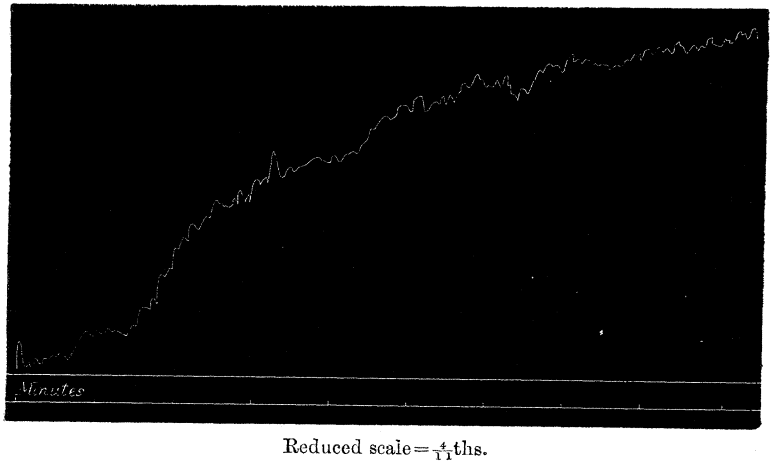
Experiment VI (Chart V (broken line, diagrammatic) and Curve V). —Taken 15′ after a full meal (contrast this with Observation III made on the same day before the meal). Large capsule employed. The animal slept the whole of the time.

0′. Sound introduced; pendulum movements for first minute.
1′. „ advanced 7 mm.
2′. „ „ 25 „
3′. Movement of all intestine.
4′. Sound advanced 60 mm. The propulsion of the sound greatly accelerated.
5′. Contractions eleven to the minute; relaxation between. Waves very imperfect.
6′. Sound advanced 111 mm.
6′ 30″. Sound advanced 142 mm. No marked pause takes place in the occurrence of the waves. A maximum rapidity of 38 mm. in the minute is attained towards the end of the curve.

Contrasting this result with Observation III gives the relative speed of the progressive peristalsis in the two cases.

Time after introduction of sound in minutes.	Sound travels	
	Before food (hunger).	15 minutes after food.
	cm.	cm.
2	5·3	2·5
	The progressive peristalsis stimulated by introduction of sound.	
4	0·2	3·5
6	0·4	5·1
7	..	3·1
8	0·8	—

Experiment VII, Curve VI.—See Chart VI.



Reduced scale = $\frac{4}{11}$ths.

The last experiment was made with a metal capsule, and in order to show that the nature of the sound has no marked influence upon the rapidity of propulsion immediately after food has been introduced into the stomach, I shall quote the results obtained when the meat sound employed in Experiment II was substituted for the metal capsule. It will be seen that whether the body to be forwarded by peristaltic movement be incompressible or soft and plastic, the result obtained is practically the same.

Experiment VI (Chart and Curve VI).—The dog had finished a full meal six minutes before introduction of the sound.

0′. Introduce meat sound deeply through the upper fistulous opening. Animal sleeping.

1′.	11 mm.	traversed.	
2′.	35 ,,	,,	Very strong peristalsis with some "roll" movements of the loop of intestine.
3′.	62 ,,	,,	
4′.	76 ,,	,,	
5′.	92 ,,	,,	Animal awake, deep respirations.
6′.	103 ,,	,,	
7′.	113 ,,	,,	Slight delay towards lower mouth of fistulous tract, the last 2 cm. of which seems occasionally to act more feebly than the rest.
8′.	119 ,,	,,	
9′.	123 ,,	,,	
9′ 30″.	131 ,,	,,	

Tabulated with the results of Experiment II (Chart I) the speed of propulsion is relatively the following :—

Time after introduction of sound in minutes.	Sound travels	
	Before food (hunger).	Six minutes after food.
	cm.	cm.
0	0	0
2	0	3·4
4	0·5	4·3
6	1	3·4
8	1	2·6
10	0·3	2·3
12	0	—
14	0·1	—
16	0·6	—

The sound traversed 11·5 cm. of the fistulous intestine of the fasting animal in 46′.
,, ,, ,, fed ,, 6·5′.

During the later stages of digestion, *i.e.*, one and a half to three hours after a full meal, the transmission of a solid body through the

fistulous intestine is fairly regular and rapid. There is, however, more tendency to occasional pauses and to the development of local non-propulsive movement which often inaugurate a phase of peristaltic activity. Four or five hours after a meal and until the recurrence of hunger—period of repletion—the progression of a solid body through the fistula is at its slowest, long pauses being frequently observed without the occurrence of any propelling contractions.

Even when peristalsis is occurring it is slow, and has much of a forward and backward character, complete relaxation behind the sound succeeding an active local contraction.

A short tabulated statement of the results of several experiments dealing with the speed of transmission of a solid body during fasting (hunger), digestion, repletion, &c., may be found useful for purposes of comparison. The average time for each centimetre of the intestine traversed is not of course of absolute value.

Condition of animal.	Length of fistulous intestine traversed.	Total time occupied.	Average time for each cm. of intestine traversed.	Sound employed.
	cm.	′ ″	′ ″	
Fasting (*a*) ..	15·25	20 30	1 30	Large metal capsule.
„ (*b*) ..	9	15 0	1 40	Small „
„ (*c*) ..	15·5	27 30	1 48	Large „
„ (*d*) ..	16	33	2	Cork, 9 mm. × 14 mm.
„ (*e*) ..	15	38	2 30	Large metal capsule.
„ (*f*) ..	12	40	3 20	Lean meat.
After exercise (*g*) ..	13·5	16 30	1 12	Large metal capsule.
Digestion (*a*)..	14·2 (15′ after food.)	6 48	0 26	Large metal capsule.
„ (*b*)..	15·5 (8′ after food.)	8 48	0 36	Lean meat.
„ (*c*)..	14·75 (2 h. 34 m. after food.)	13 36	0 54	Large metal capsule.
Repletion (*a*)..	7·5 (4 hrs. after meal.)	76	10	Large metal capsule.

(The transit in the last case I have quoted is one of the slowest I have observed. During the first 10′ there was a progression of 1·5 cm., preceded by a pause. Local non-propulsive movements followed by peristalsis succeed in 20′ (4 cm. in 9′); passage of the next 3 cm. took 36′.)

Some variation in peristalsis according to the sound employed became

evident after a few experiments had been made with each. The introduction of the larger metal sound (9 × 14 mm.) was usually followed by a well-marked peristalsis occurring immediately afterwards (Experiment III), lasting for 1′ to 3′, and propelling the sound 2 to 5 cm. into the fistula of the fasting animal. With the cork sound of equal size, but lesser weight, the effect was the same; with the narrow capsule (6 × 14 mm.) and the meat fragment, this primary peristalsis of introduction was much less marked. After the period of activity had passed, the time occupied in the transit through the entire length of the fistula appeared to be closely similar in the larger and smaller bodies; in other words, those of greater size which at first excited motion soon ceased to do so, the intestine becoming "accustomed"—as the œsophagus does—to their presence.

When a phase of activity is present, as during the time immediately succeeding the introduction of food into the stomach, all evidence that larger bodies contribute by their size to a more rapid propulsion through the fistula, is lost. (If there were greater variation in the diameter of the sounds employed than existed in those used in these experiments, it is possible that some slight exceptions to this statement might be found.)

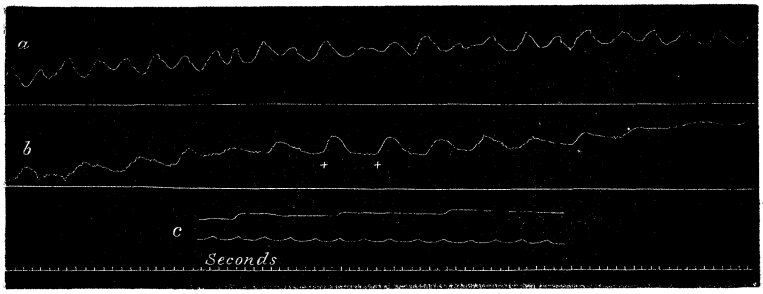
Changes in Character of Peristaltic Contractions.

It is not my purpose at the present time to enter into a minute examination of the character of individual peristaltic contractions occurring under various circumstances, although I have alluded to this question very briefly on page 214. As, however, the consideration of peristalsis, stimulated by the introduction of a large sound into the fistula, has been brought under notice, I can scarcely omit contrasting the nature of the waves produced in this manner (and which are very similar to those occurring in all portions of the fasting intestine), and the digestive peristalsis occurring in the same animal half an hour after a full meal.

It is found on registering them upon a cylinder having a medium velocity, that the contractions occurring in the first (fasting) condition are much more numerous in a given time, frequently nearly twice as many as in the latter; that the individual contractions have a shorter maximum which is attained more quickly, and that their relaxation is more abrupt and complete. As a result we find that in spite of the greater number of contractions the sound advances further in the same time after food than it did when food had not been recently administered. Some hours after the meal the change is even more striking, long periods of rest occurring which are from time to time broken by a few faint contractions, having a sustained maximum and an imperfect relaxation.

The quotation of one experiment will illustrate these facts sufficiently.

Experiment VIII, Curve VII.—Travelling Sound in Upper Fistulous Opening (quick drum).



a. Peristalsis on introduction of large sound (before feeding).
b. „ „ (after „).
c. „ in advanced stage of digestion.
„ Lower line indicates respiration.

Experiment VIII (Curve VII, *a*, *b*, *c*).—Dog fasting sixteen hours. Large travelling sound (9 × 18 mm.) introduced into upper fistulous opening. Record on drum of medium velocity.

0′. In 80″ succeeding introduction of sound twenty-three contractions occur (*a*). Average length of each contraction 3·3″. Total advance of sound 28 mm. Sound removed.

5′. Full meal of meat given to dog.

35′. Sound again placed in upper opening. (Slight irregularity in curves caused by tremor of animal, which often occurred for a time after meal, and to a lesser extent by respiratory movements.) In 80″ succeeding introduction of sound, fourteen contractions occur (*b*). Average length of "forwarding" peristaltic waves 5″. Average length of two contractions succeeded by a more complete relaxation occurring in the middle of tracing 3·3″.

Actual advance of sound 38 mm.

4 hours. At time of registration contractions take place at the rate of six and a half in 80″. Sound advances at rate of 10 mm. in 80″ (*c*). Contractions which are long maintained recur for 20″ to 60″, and are succeeded by pauses of several minutes' duration.

This change in the rhythm, character, and potentiality of the peristaltic contractions shows how extensive the range of adaptation of these movements to the necessities of the time must be.

In the experiment quoted we see (1), vigorous propulsion accomplished by frequent repetition of contraction; (2), more vigorous propulsion accomplished by fewer, but more sustained contractions; and (3), the leisure and occasional movement of the intestinal tube which would be favourable to active absorption.

Direction of Propulsion of Bodies introduced into the Fistulous Openings.

The result of an examination of this question experimentally may be given in few words.

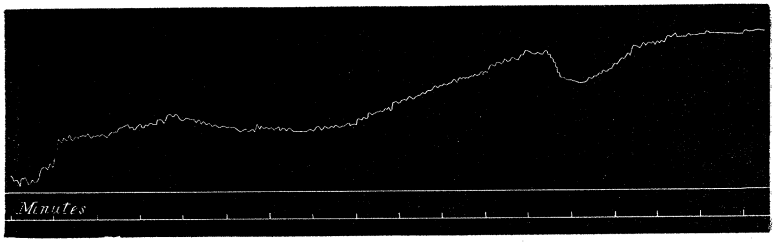
Peristaltic progression in the fistulous intestine is always in the physiological direction. If the sound be placed well within the lower mouth, it is invariably rejected from this mouth. Very occasionally a sound introduced just within the upper mouth, but not far enough to be thoroughly "gripped," may be expelled by the same opening, but after it has passed 2 cm. into the fistula, this retrogression is never seen. A slight anti-peristaltic movement observed on the introduction of water into the fistula will be described below.

Two Solid Bodies in the Fistula at the same Time.

This experiment was performed with a double sound and registering apparatus. The second sound, which was introduced after the first had passed several centimetres into the fistula, was perforated for the free passage of the thread connecting the latter with its pen. It was found that the condition of peristalsis or local contraction was not necessarily common to the whole length of the fistulous intestine, and that therefore movement of one sound occurs frequently quite independently of the other which lies within a few centimetres of it. On several occasions a distinct alternation in movement was observed, one sound resting whilst the other advanced. The first sound, *i.e.*, that nearest the lower opening of the fistula, seemed usually to travel more rapidly than the other, and therefore to gain upon it. This fact may speak for a slight stimulation originated by the presence of the upper sound when at rest, favouring a more pronounced peristalsis lower down the intestinal tube. Upon this point I am seeking for further information.

The introduction of water or almost any liquid, whether cold or at the body temperature, into the upper end of the fistula through which the sound had already passed, was invariably productive of some slight anti-peristaltic movement often associated with writhing or rolling of the intestine, the result being a retrogression of 2 or 3 cm. This reversed movement, which lasted for 2′ to 5′, was succeeded by a return of propulsive peristalsis which frequently showed a marked acceleration.

Experiment IX, Curve VIII.



Reduced scale = $\frac{1}{5}$th.

Experiment IX (Curve VIII).—Injection of 5 c.c. of water at the fourth minute into the upper fistulous opening, peristalsis being present, caused on the first occasion a relaxation lasting for 4′, and on the second, between the twelfth and thirteenth minutes, for 2′, the pen falling 18 mm. After each of these injections the peristalsis became for a time more active.

Propulsion of a Sound upon which Traction is being Exerted.

If the pen were weighted with a burden of 8 or 10 grams at a time, when the sound was being passed onwards by well-developed peristaltic movement it was found that not only was the portion of intestine in which the travelling body was situated at the moment drawn towards the mouth of the fistula, but that the powerful contractions which occurred were incapable of materially forwarding the body. Even the traction caused by applying a weight of 5 grams to the pen produced much hindrance, and the spasmodic contractions induced and which had a propulsive character created a most distinct discomfort or colic. After the removal of the hindrance to effective transmission, the intestine unfolded itself, whilst the discomfort gave place to the most evident manifestations of satisfaction on the part of the dog, and active peristalsis—which was, however, soon reduced to its orginal character—took place.

In contrasting this experiment with the well-known result obtained by Mosso, who observed that the œsophagus could hold a sound connected with a falling weight which exerted a traction of 450 grams, and forward one of but little less, the rectilineal course of the tube, and the fact that it is practically fixed at both ends—in both of which respects it acts at a far greater advantage than the intestine—must be borne in mind. I possess evidence, however, which I hope to be in a position to produce shortly, that even if these unfavourable conditions are obviated, the small intestine is physiologically unfitted for the systematic propulsion of bodies upon which more than a very

moderate degree of traction is made. Fortunately this condition of traction upon a solid body already engaged in the intestinal tube can but rarely come into operation in the animal body, or it would undoubtedly prove peculiarly difficult to overcome.

Mechanical irritation of the lower mouth or upper mouth of the fistulous intestine, if persisted in, developed a powerful peristalsis which caused the rapid passage of a solid body through the fistula and its expulsion by the lower opening. Thus if the animal was induced—which it readily was—to lick the mouth of the fistula after the sound had been inserted in the upper opening, expulsion from the lower opening occurred in four to eight minutes. By moving a glass rod—passed within the mouth of the fistula—gently round or in and outwards, the same result was occasionally produced, but not with the same speed or certainty.

The consideration of the effect of electrical stimulation and of a number of drugs, upon whose action I believe new light will be thrown by this method of experimentation, I must leave to a future paper.

I have purposely avoided entering into a discussion of the physiological *rationale* of the various phenomena I have described in this communication, because they cannot find their full explanation in the examination of a fistulous animal. This explanation must be sought by experiment of another character, and although much has been rendered clear to me by the analytical research I have already made, other points are still lacking their complete elucidation. Until the latter research appears, I likewise postpone reference to the literature of the subject.

To the Royal Society, which presented me with a donation in aid of this research, and to Prof. Hugo Kronecker, of Berne, who most kindly placed his laboratory at my disposal for its accomplishment, my best thanks are due, and I gladly take this opportunity of recording them.

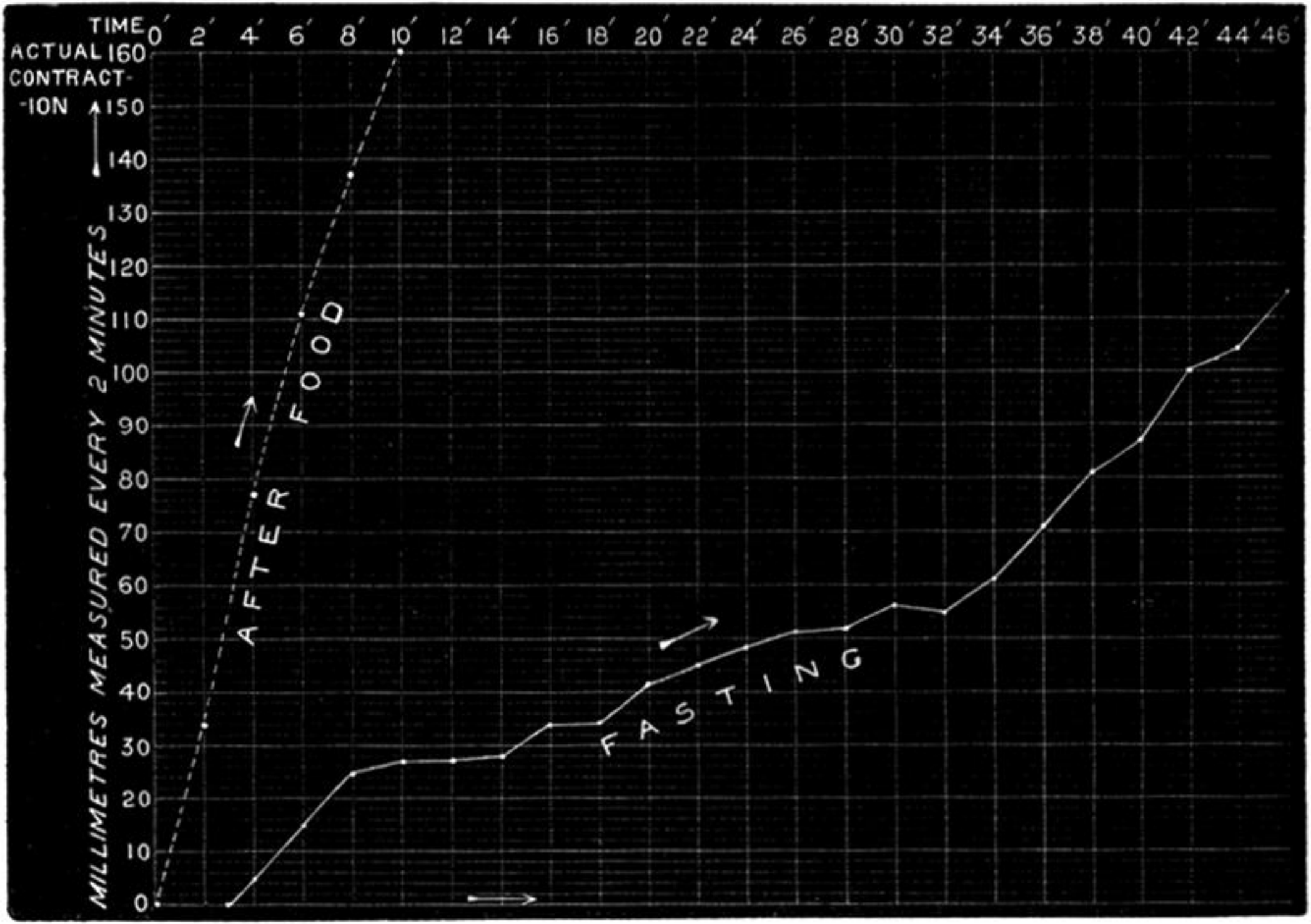
"On the Practical Measurements of Temperature. Experiments made at the Cavendish Laboratory, Cambridge."

By H. L. CALLENDAR, B.A., Scholar of Trinity College, Cambridge. Communicated by J. J. THOMSON, F.R.S., Professor of Experimental Physics at the Cavendish Laboratory, Cambridge. Received June 9.—Read June 10, 1886.

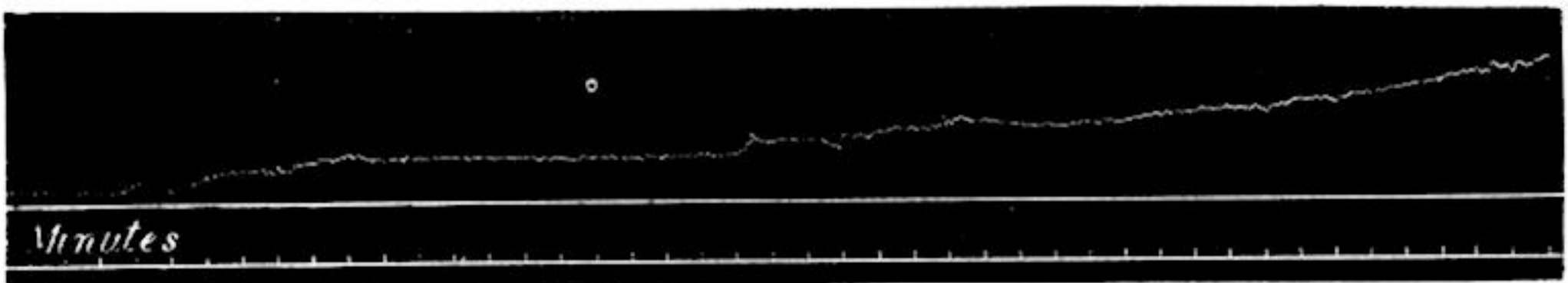
(Abstract.)

The experiments were undertaken with a view to investigate the possibility of establishing strictly comparable standards for high temperature measurements for which the air thermometer is in-

Experiment II, Chart I. Experiment VII, Chart VI.

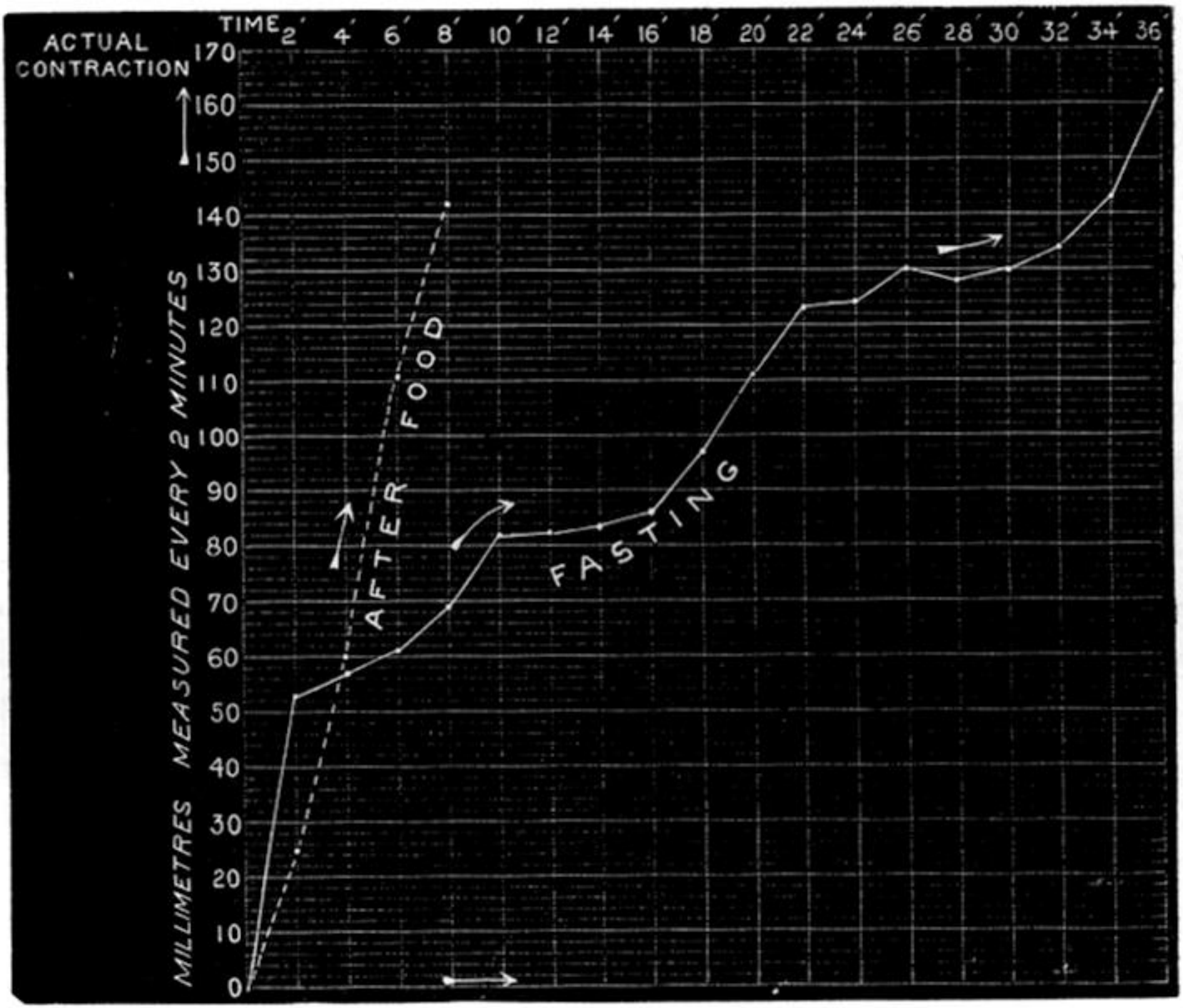


Experiment II, Curve I.

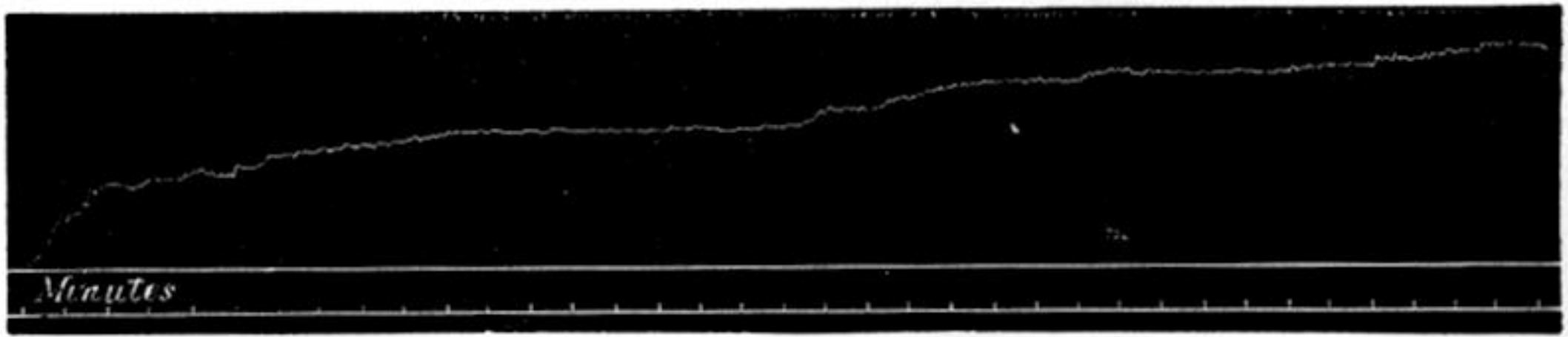


Reduced scale = $\frac{1}{7}$th.

Experiment III, Chart II. Experiment VI, Chart V.

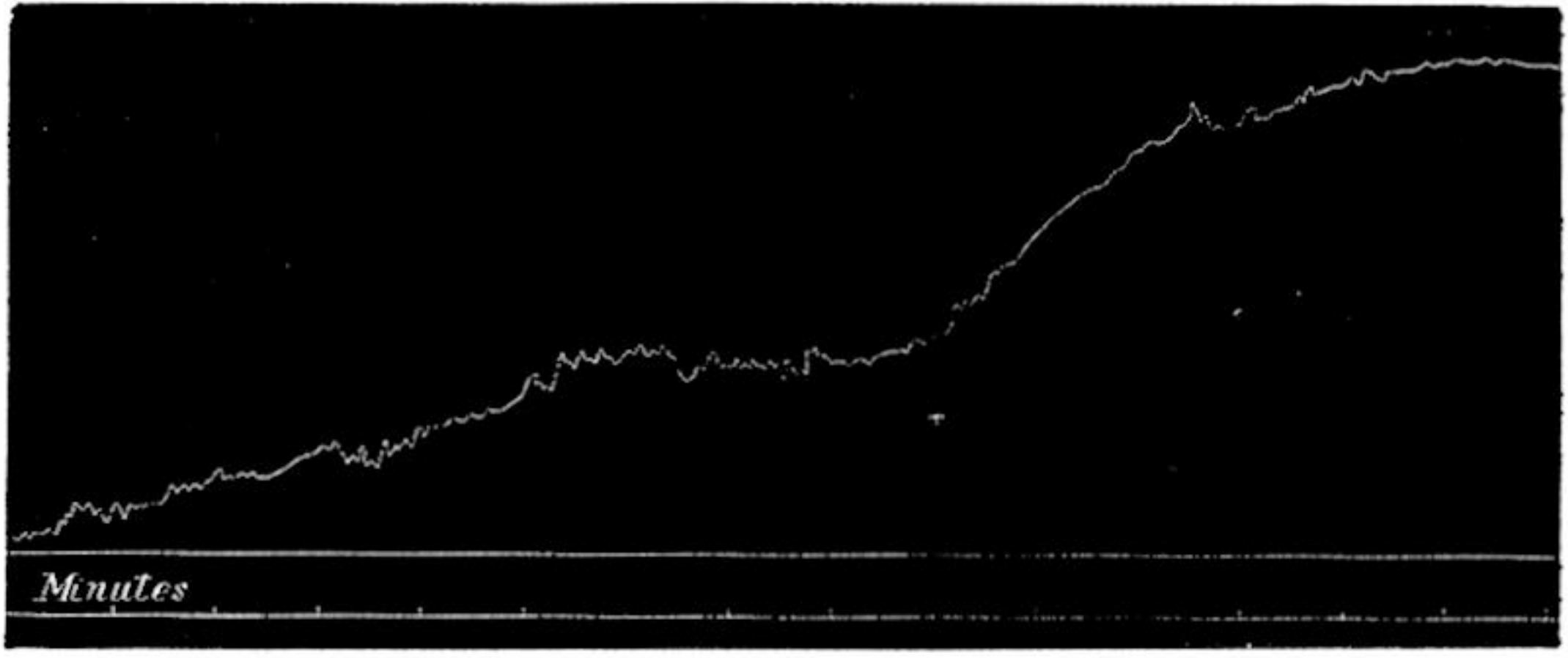


Experiment III, Curve II.

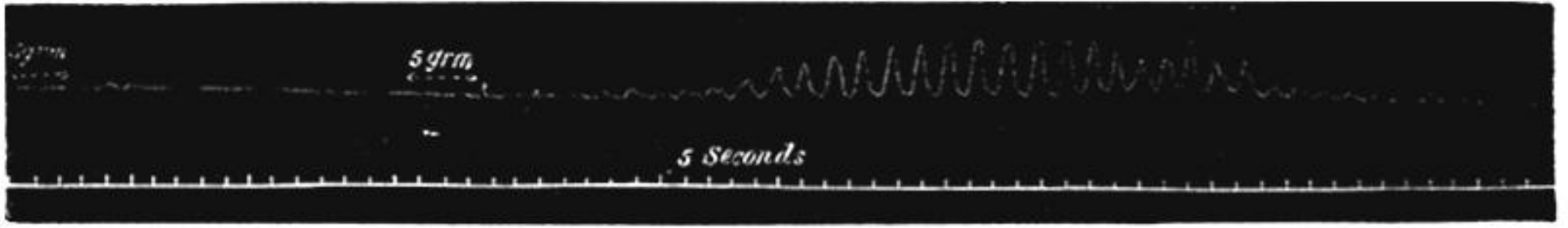


Reduced scale = $\frac{7}{39}$ths.

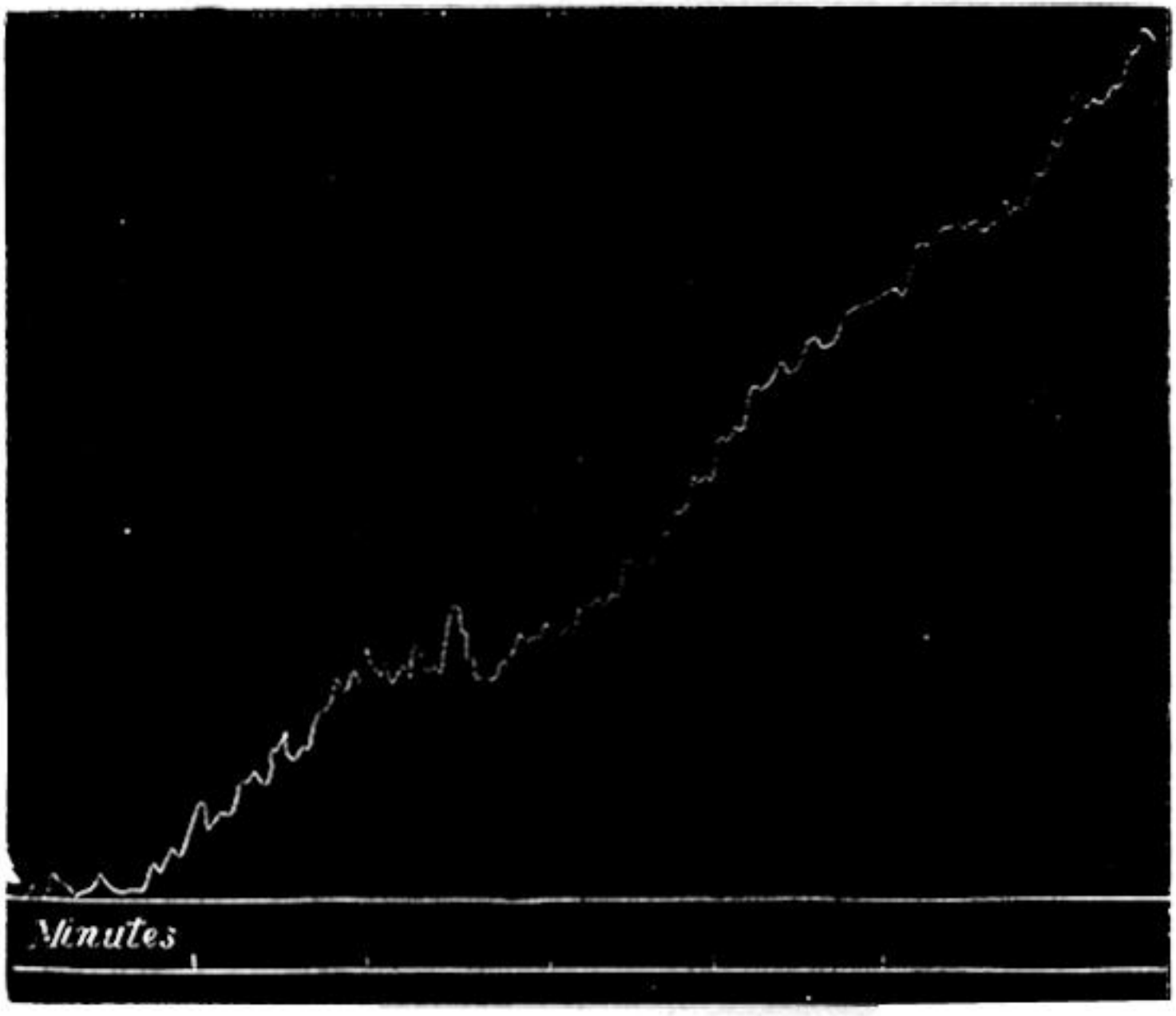
Experiment IV, Curve III.



Reduced scale = $\frac{1}{3}$th.

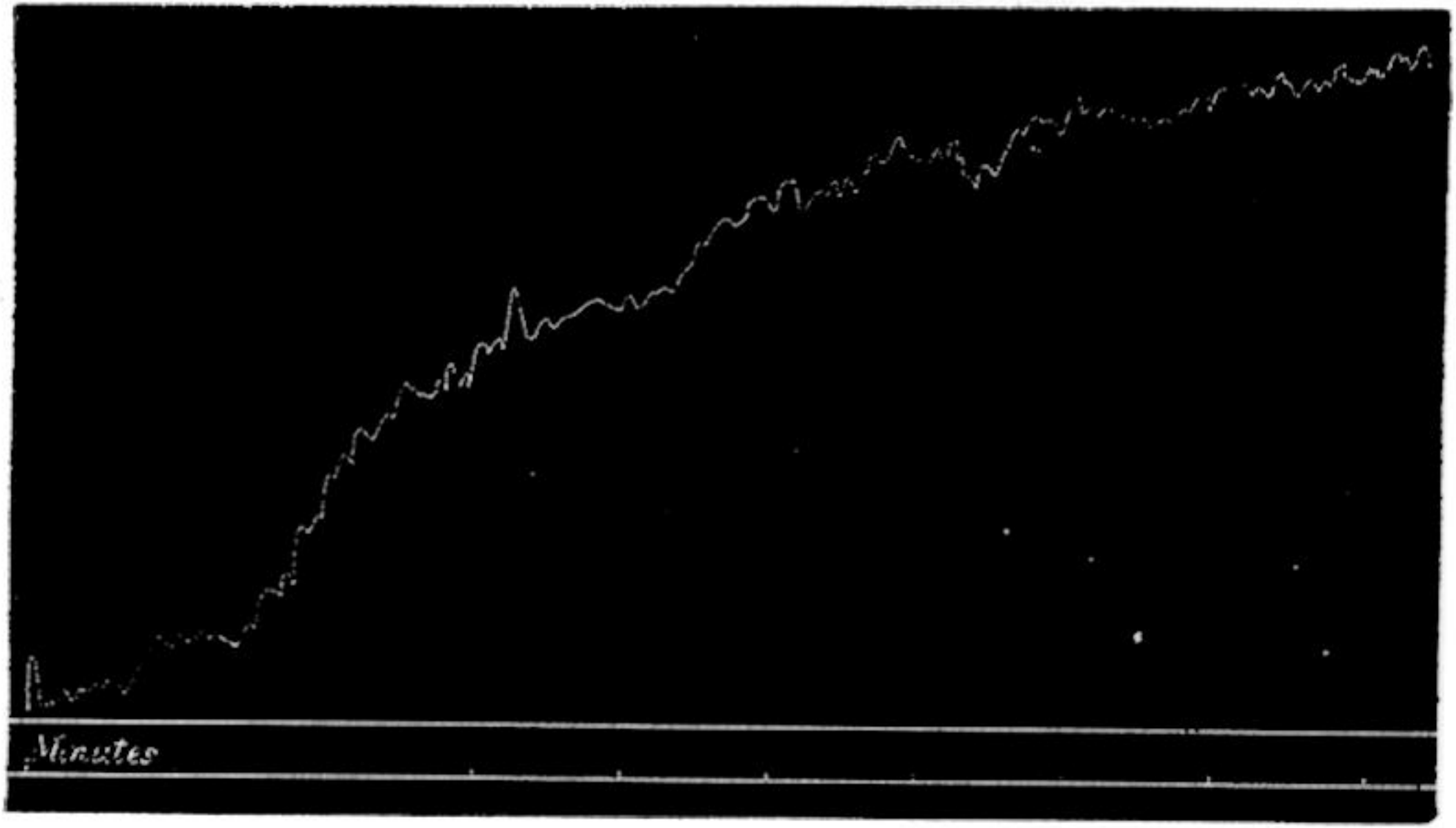

5 grm.
5 Seconds

Experiment VI, Curve V.—Fifteen minutes after full Meal.



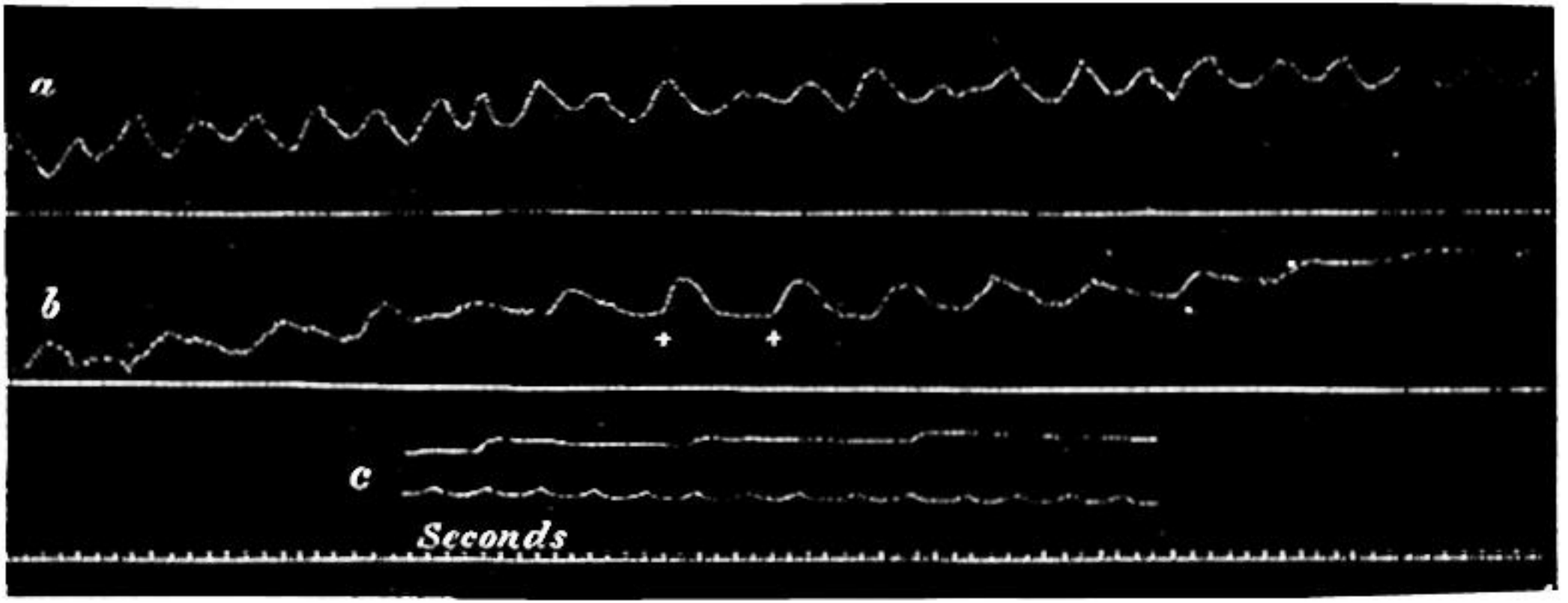
Reduced scale = $\frac{4}{11}$ths.

Experiment VII, Curve VI.—See Chart VI.



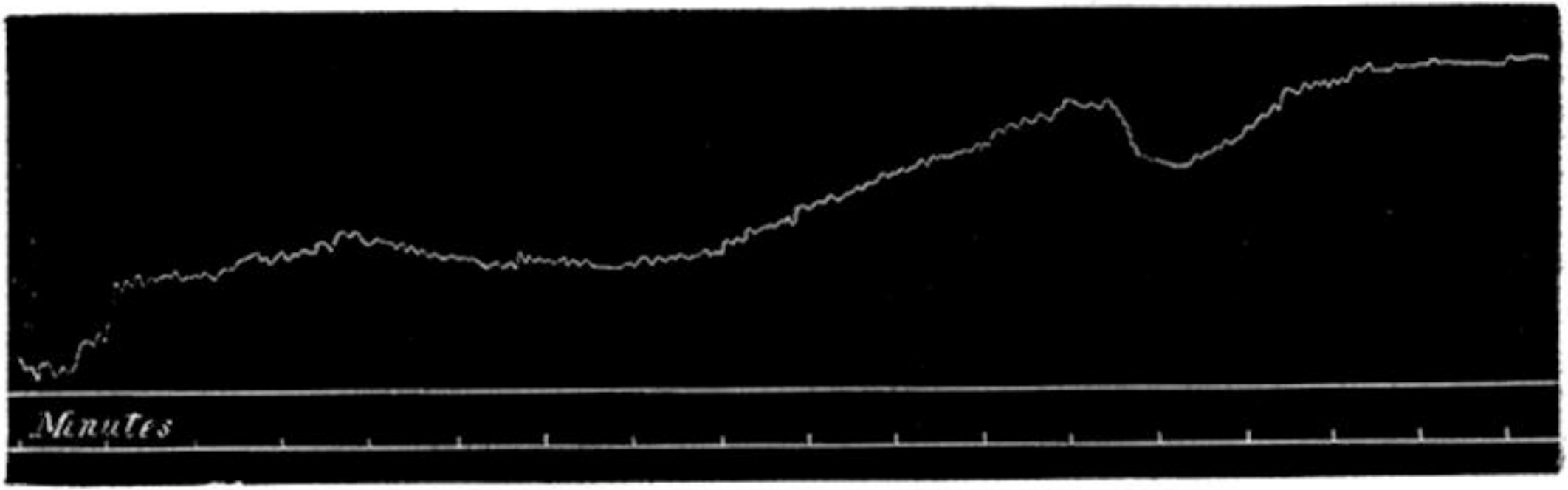
Reduced scale = $\frac{4}{11}$ths.

Experiment VIII, Curve VII.—Travelling Sound in Upper Fistulous Opening (quick drum).



a. Peristalsis on introduction of large sound (before feeding).
b. „ „ (after „).
c. „ in advanced stage of digestion.
„ Lower line indicates respiration.

Experiment IX, Curve VIII.



Reduced scale = $\frac{1}{5}$th.